Chapter 3 Lecture

Essentials of Oceanography
Eleventh Edition

Marine Provinces

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Chapter Overview

• The study of bathymetry determines ocean depths and ocean floor topography.
• Echo sounding and satellites are efficient bathymetric tools.
• Most ocean floor features are generated by plate tectonic processes.
• Different sea floor features exist in different oceanographic locations.
Bathymetry

• Measures the vertical distance from the ocean surface to mountains, valleys, plains, and other sea floor features
Measuring Bathymetry

• Soundings
  – Poseidon made first sounding in 85 B.C.
  – Line with heavy weight
  – Sounding lines used for 2000 years

• Fathom
  – Unit of measure
  – 1.8 meters (6 feet)
Measuring Bathymetry

• **HMS Challenger**
  – Made first systematic measurements in 1872

• Deep ocean floor has relief
  – Variations in sea floor depth
Measuring Bathymetry

• Echo Soundings
  – Echo sounder or fathometer
  – Reflection of sound signals
  – German ship *Meteor* identified mid-Atlantic ridge in 1925

• Lacks detail

• May provide inaccurate view of sea floor
Echo Sounding Record
Measuring Bathymetry

• Precision Depth Recorder (PDR)
  – 1950s
  – Focused high-frequency sound beam
  – First reliable sea floor maps produced
  – Helped confirm sea floor spreading
Modern Bathymetry Measuring

- **Multibeam Echo Sounders**
  - Multiple simultaneous sound frequencies

- **Seabeam**
  - First multibeam echo sounder
  - Map sea floor strips up to 60 km (37 mi) wide
Modern Bathymetry Measuring

- **Sonar**
  - Sound navigation and ranging acronym
Modern Bathymetry Measuring

• Side scan sonar
  – GLORIA (Geological Long-range Inclined Acoustical instrument)
  – Sea MARC (Sea Mapping and Remote Characterization)

• Can be towed behind ship to provide very detailed bathymetric strip map
GLORIA Side Scanning Sonar
Sea Floor Mapping from Space

• Uses satellite measurements
• Measures sea floor features based on gravitational bulges in sea surface
• Indirectly reveals bathymetry
Comparing Bathymetric Maps
Sea Floor Mapping from Space

- Satellite-derived ocean surface gravity
- Reveals bathymetry where ships have not conducted research
Measuring Bathymetry

• **Seismic Reflection Profiles**
  - Air guns
  - Strong, low-frequency sounds
  - Details ocean structure beneath sea floor
Seismic Reflection Profile
Hypsographic Curve

- Shows relationship between height of land and depth of ocean
Hypsographic Curve

- 70.8% of Earth covered by oceans
- Average ocean depth is 3729 meters
- Average land elevation is 840 meters
- Uneven distribution of areas of different depths/elevations
- Variations suggest plate tectonics at work
Ocean Provinces

Three Major Provinces

• Continental margins
  – Shallow-water areas close to shore

• Deep-ocean basins
  – Deep-water areas farther from land

• Mid-ocean ridge
  – Submarine mountain range
Ocean Provinces

Continental margin | Ocean basin floor | Mid-ocean ridge | Ocean basin floor | Continental margin
A | See cross-section above | MID-ATLANTIC RIDGE | B
NORTH AMERICA | AFRICA | EUROPE

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Continental Margins

• **Passive**
  – Not close to any plate boundary
  – No major tectonic activity
  – East coast of United States

• **Active**
  – Associated with convergent or transform plate boundaries
  – Much tectonic activity
Passive and Active Continental Margins

- Passive continental margin
  - Continental shelf
  - Continental slope
  - Continental rise
  - Abyssal plain
  - Sea level
  - Rift valley
  - Mid-ocean ridge

- Convergent active continental margin
  - Continental slope
  - Continental shelf
  - Seamounts
  - Ocean trench

Horizontal scale / Vertical scale = 50 / 5 = 10x

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Active Continental Margins

• Convergent Active Margin
  – Oceanic-continent convergent plate boundaries
  – Active continental volcanoes
  – Narrow shelf
  – Offshore trench
  – Western South America
Active Continental Margins

• Transform Continental Margin
  – Less common
  – Transform plate boundaries
  – Linear islands, banks, and deep basins close to shore
  – Coastal California along San Andreas Fault
Continental Margin Features

- Continental shelf
- Shelf break
- Continental slope
- Continental rise
Passive Continental Margin Features
Continental Shelf

• Flat zone from shore to shelf break
  – Shelf break is where marked increase in slope angle occurs.

• Geologically part of continent

• Average width is 70 km (43 miles) but can extend to 1500 km (930 miles)

• Average depth of shelf break is 135 meters (443 feet)
Continental Shelf

- Type of continental margin determines shelf features.
- Passive margins have wider shelves.
- California’s transform active margin has a continental borderland.
Continental Slope

- Where deep ocean basins begin
- Topography similar to land mountain ranges
- Greater slope than continental shelf
  - Averages 4° but varies from 1–25° gradient
- Marked by submarine canyons
Submarine Canyons

- Narrow, deep, V-shaped in profile
- Steep to overhanging walls
- Extend to base of continental slope, 3500 meters (11,500 feet) below sea level
- Carved by turbidity currents
Turbidity Currents

• Underwater avalanches mixed with rocks and other debris
• Sediment from continental shelf
• Moves under influence of gravity
• Sediments deposited at slope base
Continental Rise

- Transition between continental crust and oceanic crust
- Marked by turbidite deposits from turbidity currents
- Graded bedding in turbidite deposits
Continental Rise

- Deposits generate deep-sea fans, or submarine fans
- Distal ends of submarine fans become flat abyssal plains
Abyssal Plains

- Extend from base of continental rise
- Some of the deepest, flattest parts of Earth
- Suspension settling of very fine particles
- Sediments cover ocean crust irregularities
- Well-developed in Atlantic and Indian oceans
Abyssal Plains

- Abyssal plain
- Abyssal hill
- Fine sediment from suspension settling covers irregularities
- Basaltic oceanic crust
- Sea floor
- To ocean surface
- 2800 fathoms
- 3600 fathoms
- 0 miles to 60 miles

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Abyssal Plain Volcanic Peaks

- Poke through sediment cover
- Below sea level:
  - Seamounts, tablemounts, or guyots at least 1 km (0.6 mile) above sea floor
  - Abyssal hills or seaknolls are less than 1 km (0.6 mile) above sea floor
- Above sea level:
  - Volcanic islands
Convergent margins generate ocean trenches.
- Deepest part of oceans
- Most in Pacific Ocean
- Deepest trench – Mariana Trench at 11,022 meters (36,161 feet)
Ocean Trenches

Selected Pacific Ocean Trenches

<table>
<thead>
<tr>
<th>Name</th>
<th>Depth (km)</th>
<th>Width (km)</th>
<th>Length (km)</th>
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<tbody>
<tr>
<td>Middle America</td>
<td>6.7</td>
<td>40</td>
<td>2800</td>
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<tr>
<td>Aleutian</td>
<td>7.7</td>
<td>50</td>
<td>3700</td>
</tr>
<tr>
<td>Peru-Chile</td>
<td>8.0</td>
<td>100</td>
<td>5900</td>
</tr>
<tr>
<td>Kermadec-Tonga</td>
<td>10.0</td>
<td>50</td>
<td>2900</td>
</tr>
<tr>
<td>Kuri</td>
<td>10.5</td>
<td>120</td>
<td>2200</td>
</tr>
<tr>
<td>Mariana</td>
<td>11.0</td>
<td>70</td>
<td>2550</td>
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Atlantic Ocean Trenches

<table>
<thead>
<tr>
<th>Name</th>
<th>Depth (km)</th>
<th>Width (km)</th>
<th>Length (km)</th>
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<tr>
<td>South Sandwich</td>
<td>8.4</td>
<td>90</td>
<td>1450</td>
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<tr>
<td>Puerto Rico</td>
<td>8.4</td>
<td>120</td>
<td>1550</td>
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Indian Ocean Trenches

<table>
<thead>
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<th>Name</th>
<th>Depth (km)</th>
<th>Width (km)</th>
<th>Length (km)</th>
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<tr>
<td>Java (Sunda)</td>
<td>7.5</td>
<td>80</td>
<td>4500</td>
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Island and Continental Arcs

- **Volcanic arc** on nonsubducted ocean plate
- **Island arc**
  - Islands in ocean
  - Japan
- **Continental arc**
  - Mountains on land
  - Andes Mountains
Pacific Ring of Fire

• Margins of Pacific Ocean
• Majority of world’s active volcanoes and earthquakes
• Marked by convergent boundaries
Mid-Ocean Ridge

- Longest mountain chain
- On average, 2.5 km (1.5 miles) above surrounding sea floor
- Volcanic
- Basaltic lava
- Divergent plate boundary
Mid-Ocean Ridge
Mid-Ocean Ridge Features

• Rift Valley
  – Downdropped area on crest of ridge
  – Marked by fissures and faults
  – Small earthquakes
Mid-Ocean Ridge Features

- **Seamounts** – tall volcanoes
- **Pillow lava** or pillow basalt – shapes formed when hot basaltic lava quickly cools
Mid-Ocean Ridge Features

Hydrothermal Vents
• Sea floor hot springs
• Foster unusual deep-ocean ecosystems able to survive without sunlight
Hydrothermal Vents

- **Warm water vents** – temperatures below 30°C (86°F)
- **White smokers** – temperatures from 30–350°C (86–662°F)
- **Black smokers** – temperatures above 350°C (662°F)
Hydrothermal Vents

[Diagram showing the process of hydrothermal vents]

- Ridge crest
- Metal sulfide deposits
- Black smoker
- Infiltration of seawater
- Magma chamber (heat source)
Fracture Zones and Transform Faults

• **Transform faults** along mid-ocean ridge offset spreading zones.
  – Linear ridge on spherical Earth
  – Seismically active

• **Fracture zones** along Pacific Ocean mid-ocean rise
  – Seismically inactive
  – Occur beyond offset fragments of rise
Fracture Zones

1. Past
   - East Pacific Rise

2. More Recent
   - East Pacific Rise
   - East Pacific Rise
   - Eltanin Fracture Zone and transform fault

3. Today
   - East Pacific Rise
   - Eltanin Fracture Zone

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Fracture Zones and Transform Faults

<table>
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<tr>
<th></th>
<th>Transform faults</th>
<th>Fracture zones</th>
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<tbody>
<tr>
<td>Plate boundary?</td>
<td>Yes—a transform plate boundary</td>
<td>No—an intraplate feature</td>
</tr>
<tr>
<td>Relative movement across feature</td>
<td>Movement in opposite directions</td>
<td>Movement in the same direction</td>
</tr>
<tr>
<td></td>
<td>↔</td>
<td>↔</td>
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<tr>
<td>Earthquakes?</td>
<td>Many</td>
<td>Few</td>
</tr>
<tr>
<td>Relationship to mid-ocean ridge</td>
<td>Occur <em>between</em> offset mid-ocean ridge segments</td>
<td>Occur <em>beyond</em> offset mid-ocean ridge segments</td>
</tr>
<tr>
<td>Geographic examples</td>
<td>San Andreas Fault, Alpine Fault, Dead Sea Fault</td>
<td>Mendocino Fracture Zone, Molokai Fracture Zone</td>
</tr>
</tbody>
</table>
Fracture Zones and Transform Faults
Oceanic Islands

- Volcanic activity
- Hotspots
- Island arcs
- Islands that are part of continents
End of CHAPTER 3
Marine Provinces